The Structural Behavior of Historical Columns in Jerash City, Jordan

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Jerash is an old Roman city which used to be called Gerasa in ancient times and is located about 48km to the North of Jordan's capital, Amman. It is considered one of the largest and better preserved sites of Roman architecture in the world outside Italy. Till this day, its paved and colonnaded streets, theaters, temples, public squares and city gates remain in fabulous condition. It went through many historical events, where the most critical one was the earthquake of 749 AD. Nevertheless, the columns in Jerash city are one of the most outstanding features, which can be found either as free standing columns without being connected with any structural element, or as colonnades, which are columns connected together by a beam at the top. Most of the columns in Jerash city were following the Greek architecture, in which the Romans embraced Greek culture that became the foundation of Roman culture in Jerash, where architecture emerged largely from the adoption and reshaping of Greek models [1]. From this point comes the historical value and rarity of the columns in Jerash, as a significance national treasure that must be preserved by starting a deep and detailed study with respect to the structural behaviour of the columns and represent the optimal key for having a strategy of preservation.

By going through the world earthquake prone map, most of countries around the Mediterranean Sea are subjected to high intensity earthquakes, which causes destruction of ancient monuments, so it was important for the old nations to construct structures with the ability to resist the seismic actions. They have used the multi-drum technique in constructing the columns by using stones that are placed on top of each other, usually without connection material between the individual blocks [2]. This is the same technique used for constructing the columns in Jerash. Hence, understanding the behaviour and response of the multi drums during earthquakes is useful for the assessment of conservation and rehabilitation proposals for such structures in Jerash city.

The structural behaviour of multi-drum columns during seismic actions acts as rocking and sliding in between the stone blocks itself, either individually or in groups, resulting in several modal shapes [3]. Most the columns in Jerash city have been constructed in a way to resist the seismic actions by using multi drum system, in which the columns ranges with different heights and composed of around seven to five drums and a capital in some cases. The diameters of the drums decrease from the base to the top. In some columns, the drums are connected with metal pins, which is a system called 'polos-empolio'[4], helps to dissipate the seismic energy and achieve stable contact between the drums. Through the researches that have been done for simulating the structural behaviour of multi-drum columns, it shows the structural behaviour is so susceptible for the effects of small disturbance, such as damping coefficients and the contact stiffness. Where the drums tend to be stable and have slightly sliding in the contact surface between each other in larger frequencies, beside instability and complete failures for low values of frequencies and high accelerations, due to the reduction of the sliding effect with high coefficients of friction between the drums. Generally, the multi drums columns are acting with different behaviour with respect to ground accelerations. For triggering the rocking or sliding behaviour of the columns, it requires a decrease in acceleration

as the frequency increases, and the needed acceleration for overturning the column increases as the frequency increases. Which means that the columns tend to collapse at the bottom part with low PGA, while the collapse take a place with high PGA at the upper part of the column. [5-6].

As a result of studying the structural behaviour of multi drums columns, it emerged that the size and the connection between drums of the column are the significant factor for stability. Single and unconnected columns can be more unstable such as the case of free standing columns which are more susceptible to earthquakes than colonnades columns connected by beams. And this is what obviously can be seen by walking around Jerash city, where most of the destroyed columns are that have not been connected together, where colonnades columns has better capacity in dissipating the seismic energy than the free standing columns. This should guide us to have more attention for protecting the free standing columns in Jerash from one side, and rebuild the destroyed columns by using 'polos-empolio' system from the other side, in order to ensure better structural performance and stability during future earthquakes. Beside, through studying these simple columns and the historical mechanism used for resisting the earthquake with simple techniques by multi drum columns and 'polos-empolio' system, it opens our eyes for applying this kind of system in the modern structural. Where further studies should be done.

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